RADIATION SAFETY STUDY GUIDE FOR USERS OF RADIOACTIVE MATERIAL

Environment, Safety, Health and Assurance
Ames Laboratory-USDOE

APPROVAL RECORD

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1.0 INTRODUCTION

Ames Laboratory, in conjunction with the Department of Energy (DOE), is firmly committed to having a radiological control program of the highest quality. This program, as outlined in the Ames Laboratory Radiological Protection Program (RPP) Plan and mandated by Title 10, Code of Federal Regulations, Part 835 (10 CFR 835), requires that managers and supervisors at all levels be involved in planning, scheduling and conducting radiological work. This directive also requires that adequate radiological safety shall not be compromised to achieve production or research objectives.

At the Ames Laboratory, each new project involving the use of a radiological material must be approved by the Laboratory's Safety Review Committee via the Readiness Review process. This approval includes specific authorization by Environment, Safety, Health & Assurance (ESH&A), Radiation Safety Officerand by the As Low As Reasonably Achievable (ALARA) Committee. All changes to previously approved projects, such as the addition of new personnel, require the approval of ESH&A. No student or member of the Ames Laboratory staff or ISU faculty in Ames Laboratory space may use radioactive materials without this written approval. Additional details concerning application for initial authorization of a project are contained in the Ames Laboratory Radiological Protection Program Plan. Requirements for the authorization of an individual to work on a previously approved project are described in the subsections below.

This study guide should be used as a companion to the Ames Laboratory Radiological Protection Program (RPP) Plan. The RPP describes the radiation protection program to the radiation workers at Ames Laboratory.

All individuals who wish to use radioactive materials at the Ames Laboratory must become Radiological Worker II (RWII) certified. This is accomplished by reviewing this guide and successfully passing the associated examination. Additional authorization requirements are also addressed in this guide. Questions concerning this guide or the authorization process should be directed to ESH&A at 294-2153. Radiological Worker I (RWI) certification track is assigned to facilities craftsmen, not to researchers.

1.1 Training Requirement

The purpose of this study guide is to assist Ames Laboratory personnel designated as Radiological Workers in preparing for and taking the "challenge examination". This study guide represents the first half of the Radiological Worker Qualification Course, and presents the required subjects as self-study course in lieu of the 16-hour classroom course. Many research personnel prefer this qualification method for scheduling and efficiency purposes. When an individual is confident that he/she is ready, the ESH&A Office will administer a challenge exam. The individual must demonstrate his/her knowledge of the material by achieving a minimum score of 80% on the examination.

Upon successful completion of the challenge exam, he/she is then eligible to take the second half of the Radiological Worker Course, which is the practical examination, administered by ESH&A's Health Physics Group. Completion of Radiological Worker Training provides the participant with the necessary knowledge to work safely in areas controlled for radiological purposes using proper radiological practices, as specified in 10 CFR 835, and the Ames Laboratory Radiological Protection Program (RPP).

1.2. On the Job Training

The Group Leader or appropriately trained alternate must provide practical, hands-on training for the respective radioactive material experimentation processes to be conducted.

After receiving authorization from the ESH&A Health Physics Group and receiving your dosimetry you may begin using the radioactive materials under the supervision of your Group Leader or designee.

1.3. RWII Retraining

All individuals who use radiological material at Ames Laboratory must possess a basic understanding of ionizing radiation, its potential hazards, and the rules and regulations governing radiological material usage. 10 CFR 835 requires retraining, including a practical factors module, every 24 months. Contact the Ames Laboratory Training Office for more details.

1.4. Regulations and Guidance

The Code of Federal Regulations, 10 CFR 835, "Occupational Radiation Protection" is the authoritative compliance document for occupational radiation protection at Department of Energy (DOE) sites. . To implement this regulation, the Ames Laboratory Radiological Protection Program (RPP) states how each of the safety requirements will be accomplished at the Laboratory. The RPP presents the information and procedures that must be understood and practiced in order to ensure that all uses of radiological material at Ames Laboratory are in compliance. Any resultant radiation exposures must be maintained As Low As Reasonable Achievable (ALARA). Additional guidance is provided by reviewing DOE Guide 441.1-1C, "Radiation Protection Programs Guide for use with Tittle 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection.

Section Assessment #1

1) *What is the primary Federal Regulation that requires Ames Laboratory to have an occupational radiation protection program?*
2) *What is the name of the process by which the Ames Laboratory Safety Review Committee gives approval to research activities?*
3) *What is the frequency of refresher training for individuals who use radioactive materials?*
4) *What is the authorization process for the use of sources of ionizing radiation? See the Ames Laboratory's Radiation Protection Program Plan# 10202.004*

2.0 RADIATION PROTECTION BASICS

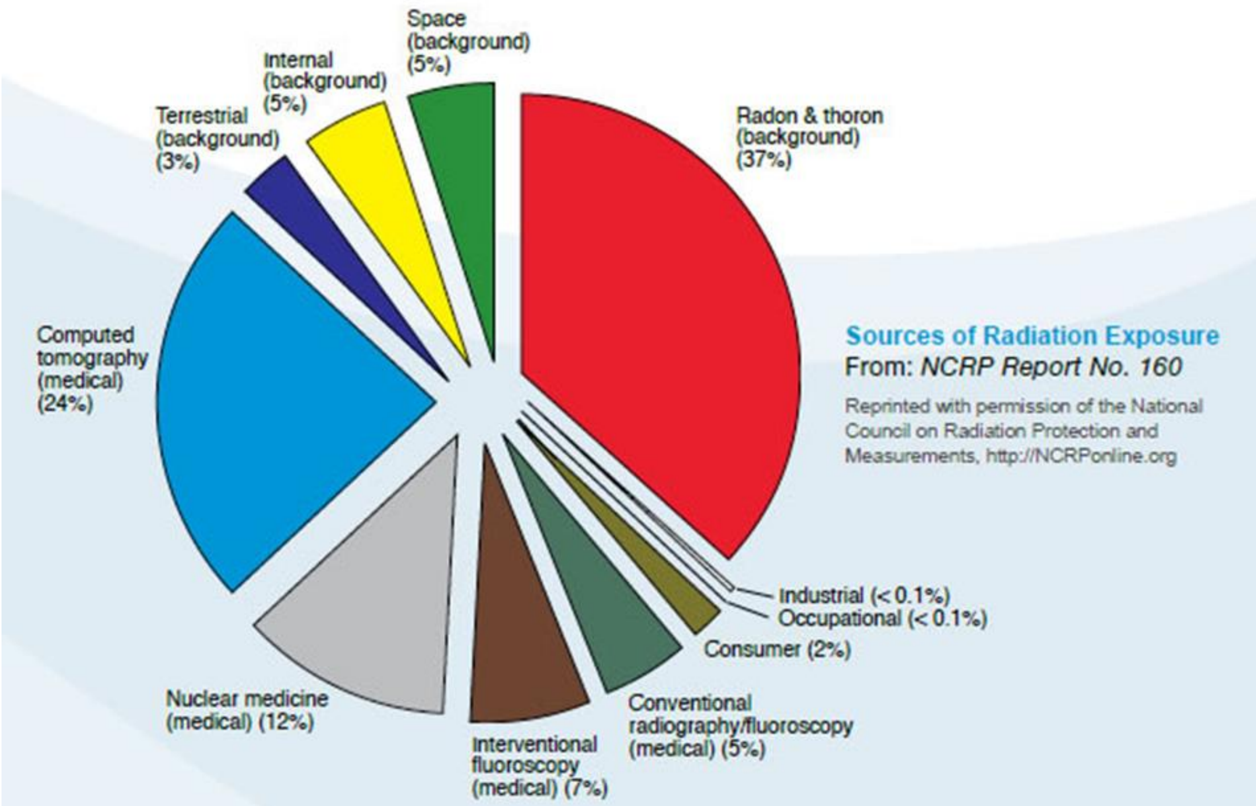
Radiation as used in this study guide refers to alpha particles, beta particles, gamma rays, X-rays, neutrons, high-speed electrons, high speed protons, and other particles capable of producing ions. Radiation that has enough energy to cause ionization is called ionizing radiation. Non-ionizing radiation, such as radio or microwaves, or visible, infrared, or ultraviolet light, is not included in the definition of radiation within this guide.

An atom usually has a number of electrons equal to the number of protons in its nucleus, so the atom is electrically neutral. A charged atom, called an *ion,* can have a positive or negative charge. An ion is formed when ionizing radiation interacts with an orbiting electron and causes it to be ejected from its orbit, a process called *ionization.* This leaves a positively charged atom (or molecule) and a free electron. Simply put, ionizing radiation can cause ionization of material by removing electrons from atoms as it moves through matter.

2.1. Background radiation

Background radiation comes from both natural and manmade sources. Natural background radiation can be categorized as cosmic and terrestrial. Radon is the major contributor to terrestrial background. The most common sources of manmade background radiation are medical procedures and consumer products.

The average background dose to the general population from both natural and manmade sources is about 620 mrem per year to the whole body. Naturally occurring sources contribute an average of 230 mrem per year from radon daughters, about 30 mrem per year from internal emitters such as potassium-40, about 30 mrem per year from cosmic sources, and about 20 mrem per year from terrestrial sources such as naturally occurring uranium and thorium. Manmade sources contribute an average of about 310 mrem per year to the whole body from medical procedures such as chest X-rays (6.5% of this is from consumer products). (Data is from the National Council on Radiation Protection and Measurements, NCRP report 160.)



2.2. ALARA

The effects of chronic exposure to low levels of radiation are not exactly known. It is assumed that there is a small risk to any dose. With this in mind the principle of keeping doses of radiation **A**s **L**ow **A**s **R**easonably **A**chievable (ALARA) is a major part of radiation safety policy at Ames Laboratory. See the Laboratory's ALARA Policy for more details.

2.3. Exposure Reduction Techniques

How can exposure to radiation be minimized? There are three physical factors that affect the exposure to radiation.

- **Distance:** Exposure varies as the inverse square of the distance (assuming a point source, as from scattering). Maximize the distance by moving away from the source of the radiation. (Inverse square law, $I_2 = I_1 ((D_1)^2/(D_2)^2)$)
- **Time:** Exposure increases linearly with time. Decrease the time spent in a radiation area by planning ahead.
- **Shielding:** Exposure is inversely exponential with the thickness of shielding. Use shielding appropriate for the type of radiation. Lead, concrete, and steel are effective in shielding against X-rays and gamma ray sources.

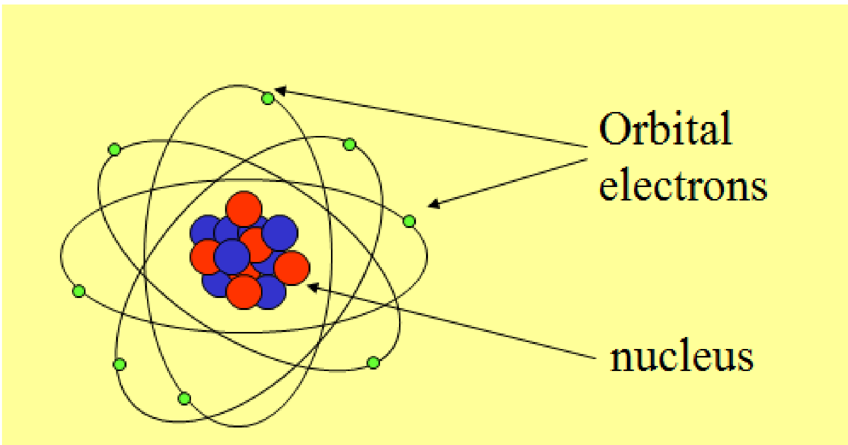
Section Assessment #2

1) *List the three methods for reducing radiation exposure.*
2) *What does ALARA mean relative to occupational radiation exposures?*

3.0 RADIOLOGICAL FUNDAMENTALS

3.1 Atomic Structure

The basic unit of matter is the atom. The central portion of the atom is the nucleus, which consists of protons and neutrons. Electrons orbit the nucleus similar to the way planets orbit our sun. The three basic particles of the atom are protons, neutrons, and electrons.



Protons:
- Protons are located in the nucleus of the atom.
- Protons have a positive electrical charge.
- The number of protons in the nucleus determines the element.
- If the number of protons in an atom changes, the element changes.

Neutrons:
- Neutrons are located in the nucleus of the atom.
- Neutrons have no electrical charge.
- Atoms of the same element have the same number of protons, but can have a different number of neutrons.
- The atoms of the same element, which have the same number of protons but different numbers of neutrons, are called isotopes.
- Isotopes have the same chemical properties; however, the nuclear properties can be quite different.

Electrons:
- Electrons are in orbit around the nucleus of an atom.
- Electrons have a negative electrical charge.
- Electrons determine the chemical properties of an atom.

Charge of the atom: The number of electrons and protons determines the overall electrical charge of the atom. The term ion is used to define atoms or groups of atoms that have a positive or negative electrical charge.

- No charge (neutral) - If the number of electrons equals the number of protons, the atom is electrically neutral and does not have an electrical charge.
- Positive charge (+) - If there are more protons than electrons, the atom is positively charged.
- Negative charge (-) - If there are more electrons than protons, the atom is negatively charged.

Stable and unstable atoms: Only certain combinations of neutrons and protons result in stable atoms.

- If there are too many or too few neutrons for a given number of protons, the resulting nucleus will have too much energy and will not be stable.
- The unstable atom will try to become stable by giving off excess energy in the form of particles or waves (ionizing radiation). These unstable atoms are also known as radioactive atoms.

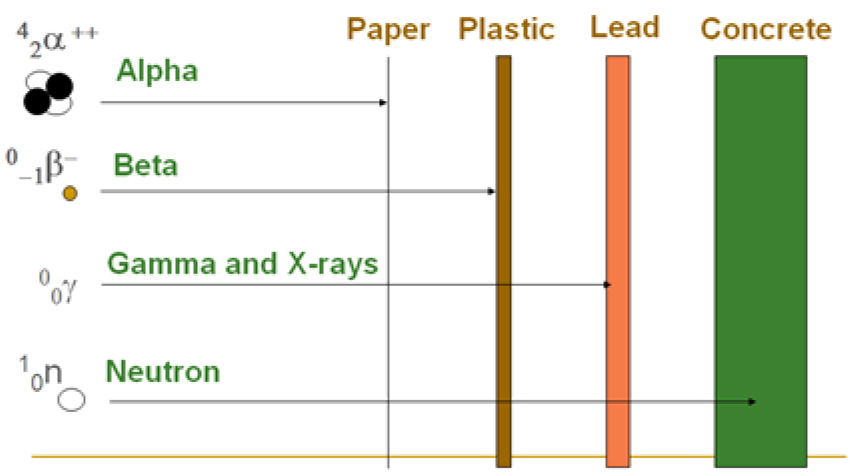
3.2 Definitions

Review definitions for the following words in Section 16.0.
- Ionization
- Ionizing radiation
- Non-ionizing radiation
- Radioactive material
- Radioactive contamination
- Radioactivity
- Radioactive decay
- Radioactive half-life

3.3 The Four Basic Types of Ionizing Radiation

The four basic types of ionizing radiation of concern in the nuclear industry are alpha particles, beta particles, gamma rays and neutron particles. Figure 1 shows radiation types, notes their atomic makeup and shows shielding type per the ionizing radiation type. These four types of ionizing radiation are placed into two general categories; particles and photons. Alpha, beta and neutrons have mass whereas gamma rays and x-rays have no mass, they are photons.

The Four Basic Types of Ionizing Radiation **(Figure 1)**



Alpha particles:

- *Physical characteristics*
  The alpha particle has a large mass and consists of two protons, two neutrons and no electrons. (Positive charge of plus two.) It is a highly charged particle that is emitted from the nucleus of an atom. The positive charge causes the alpha particle (+) to strip electrons (-) from nearby atoms as it passes through the material, thus ionizing these atoms.

- *Range*
  The alpha particle deposits a large amount of energy in a short distance of travel. This large energy deposit limits the penetrating ability of the alpha particle to a very short distance. This range in air is about three-five centimeters.

- *Shielding*
  Most alpha particles are stopped by a few centimeters of air, a sheet of paper, or the dead layer (outer layer) of skin.

- *Biological hazard*
  Alpha particles are not considered an external radiation hazard. This is because they are easily stopped by the dead layer of skin. Should an alpha emitter be inhaled or ingested, it becomes a source of internal exposure. Internally, the source of the alpha radiation is in close contact with body tissue and can deposit large amounts of energy in a small volume of body tissue.

Beta particles:

- *Physical characteristics*
  An atom and has an electrical charge of minus one. Beta radiation causes ionization by displacing electrons from their orbits. The beta particle is physically identical to an electron. Ionization occurs due to the repulsive force between the beta particle (-) and the electron (-), which both have a charge of minus one.

- *Range*
  Because of its negative charge, the beta particle has a limited penetrating ability. Range in air is about 10 feet.

- *Shielding*
  Most beta particles are shielded by plastic, glass, metal foil, or safety glasses.

- *Biological hazard*
  If ingested or inhaled, a beta emitter can be an internal hazard due to its short range. Externally, beta particles are potentially hazardous to the skin and eyes.

Gamma rays/x-rays:

- *Physical characteristics*
  Gamma/x-ray radiation is an electromagnetic wave or photon and has no electrical charge. Gamma rays are very similar to x-rays. The only difference is in the place of origin. Gamma/x-ray radiation can ionize as a result of direct interactions with orbital electrons. The energy of the gamma/x-ray radiation is transmitted directly to its target.

- *Range*
  Because gamma/x-ray radiations have no charge and no mass, they have a very high penetrating power. Range in air is very far. It will easily go several hundred feet.

- *Shielding*
  Gamma/x-ray radiations are best shielded by very dense materials, such as concrete, lead or steel.

- *Biological hazard*
  Gamma/x-ray radiation can result in radiation exposure to the whole body.

Neutron particles:

- *Physical characteristics*
  Neutron radiation consists of neutrons that are ejected from the nucleus. A neutron has no electrical charge. Due to their neutral charge, neutrons interact with matter either directly or indirectly. A direct interaction occurs as the result of a collision between a neutron and a nucleus. A charged particle or other ionizing radiation may be emitted during these interactions, which can cause ionization in human cells. This is called indirect ionization.

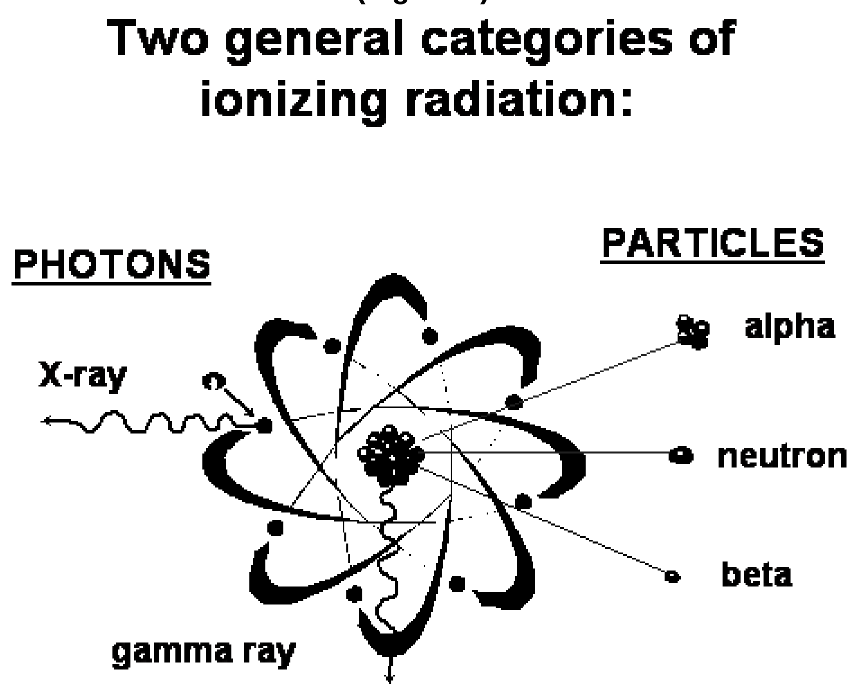
- *Range*
  Because of the lack of a charge, neutrons have a relatively high penetrating ability and are difficult to stop. Range in air is very far. Like gamma rays, they can easily travel several hundred feet in air.

- *Shielding*
  Neutron radiation is best shielded by materials with high hydrogen content, such as

water or plastic.

- *Biological hazard*
  Neutrons are a whole body hazard due to their high penetrating ability.

(Figure 2)



Section Assessment #3

1) Name five types of ionizing radiation and give characteristics of each.

4.0 RADIATION QUANTITIES AND TERMS

The following quantities and terms are essential to the description and measurement of various forms of ionizing radiation.

4.1 Exposure

Radiation safety exposure is a measure of the strength of a radiation field at a specific measuring point. It is usually defined as the amount of charge (i.e., sum of all ions of one sign) produced in a unit mass of air when the interacting photons are completely absorbed in that mass. The most commonly used unit of exposure is the "roentgen" (R) which is defined as that amount of X or gamma radiation which produces 2.58 x 10^{-4} coulombs of charge per kilogram of dry air. In cases where exposure is to be expressed as a rate, the unit would be R/hr or, more commonly, milli-roentgen per hour (mR/hr).

4.2 Absorbed Dose

Whereas exposure is defined for air, the absorbed dose is the amount of energy imparted by radiation to a given mass of any material. The most common unit of absorbed dose is the "rad" which is defined as 1 joule of energy per kilogram tissue. Absorbed dose may also be expressed as a rate with units of rad/hr or milli-rad/hr.

4.3 Dose Equivalent

Although the biological effective doses of radiation are dependent upon the absorbed dose, some types of particles produce greater effects than others for the same amount of energy imparted. In order to account for these variations when describing human health risk from radiation exposure, the quantity “dose equivalent” is used. This is the absorbed dose multiplied by certain “quality” and “modifying” factors indicative of the relative biological-damage potential of the particular type of radiation. The unit of dose equivalent is the “rem” or “milli-rem.” Dose equivalent may likewise be expressed as a rate with units of rem/hr or milli-rem/hr. For gamma or X-ray exposures, the numerical value of the rem is essentially equal to that of the rad.

4.4 Shielding

Shielding is any material placed around or adjacent to a source of penetrating radiation for the purpose of attenuating the exposure rate from the source. For shielding Gamma/X-ray radiation, materials composed of high atomic number elements such as lead are highly effective.

4.5 Half-Value Layer

The half-value layer is that thickness of a given material (i.e. shielding) that reduces the exposure rate from a source of gamma or X-rays to one-half its unshielded value.

Units

	Activity	Absorbed dose	Biological effective dose
Traditional Unit	Curie	Rad	Rem
SI unit	Becquerel	Gray	Sievert

Section Assessment #4

1) *Define the following terms:*

- *Exposure*
- *Absorbed Dose*
- *Dose Equivalent*
- *Shielding*
- *Half-value Layer*

5.0 BIOLOGICAL EFFECTS OF IONIZING RADIATION

The energy deposited by ionizing radiation as it interacts with matter may result in the breaking of bonds causing ionizations of atoms which affect molecules. If the irradiated matter is living tissue, such chemical changes may result in altered structure or function of constituent cells. These changes may in turn be manifested as one or more possible effects at the level of the organism.

5.1 Mechanisms of Radiation Damage

Because the cell is composed mostly of water, less than 20% of the energy deposited by ionizing radiation is absorbed directly by macromolecules. More than 80% of the energy deposited in the cell is absorbed by water molecules with the resultant formation of highly reactive free radicals:

H_20 ----> $H^+ + OH^-$

These radicals and their products (e.g., hydrogen peroxide) may initiate numerous chemical reactions, which result in damage to macromolecules and a corresponding alteration of structure or function. Damage produced within a cell by the radiation-induced formation of free radicals is described as being an indirect action of radiation.

5.2 Cellular Sensitivity to Radiation

The cell nucleus is the major site of radiation damage leading to cell death. This is due to the importance of the DNA within the nucleus in controlling all cellular function. Damage to the DNA molecule may prevent it from providing the proper template for the production of additional DNA or RNA. This hypothesis is supported by research, which has shown that cells are most sensitive to radiation damage during reproductive phases (i.e., during DNA replication). In general, it has been found that cell radio-sensitivity is directly proportional to reproductive capacity and to the degree of cell differentiation. Table 1 presents a list of cells, which generally follow this principle.

Table 1 - List of Cells in Order of Decreasing Radio-sensitivity

Very radio-sensitive
- mature lymphocytes (white blood cells)
- erythroblasts (immature red blood cells)
- spermatagonia (sperm-producing cells)
- basal cells (innermost layer of skin)
- endothelial cells (part of blood vessel and lymphatic vessels cell walls)

Moderately radio-sensitive
- osteoblasts (cell that synthesize bone)
- granulocytes and osteocytes (type of white blood cells)
- sperm
- erythrocytes

Relatively radio-resistant
- fibrocytes (connective tissue proteins)
- chondrocytes (found in cartilage)
- muscle and nerve cells

The considerable variation in the radio-sensitivities of various tissues is due, in part, to the differences in the sensitivities of the cells that compose the tissues. Also important in determining tissue sensitivity are such factors as the state of nourishment of the cells, interactions between various cell types within the tissue, and the ability of the tissue to repair itself.

The relatively high radio-sensitivity of tissues consisting of undifferentiated, rapidly dividing cells suggest that, at the level of the human organism, a greater potential exists for damage to the fetus or young child than to an adult for a given dose. This has, in fact, been observed in the form of increased birth defects following irradiation of the fetus and an increased incidence of certain cancers in individuals who were irradiated as children.

5.3 Human Health Effects

The effects of ionizing radiation described at the level of the human organism can be divided broadly into two categories: stochastic or non-stochastic effects.

5.3.1 Stochastic Effects

As implied from the name, "stochastic", these are effects that occur by chance. Stochastic effects caused by ionizing radiation consist primarily of genetic effects and cancer. As the dose to an individual increases, the probability that cancer or a genetic effect will occur also increases. However, at no time, even for high doses, is it certain that cancer or genetic damage will result. Similarly, for stochastic effects, there is no threshold dose below which it is relatively certain that an adverse effect cannot occur. In addition, because stochastic effects can occur in unexposed individuals, one can never be certain that the occurrence of cancer or genetic damage in an exposed individual is due to radiation.

5.3.2 Non-stochastic Effects

Unlike stochastic effects, non-stochastic effects are characterized by a threshold dose below which they do not occur. In addition, the magnitude of the effect is directly proportional to the size of the dose. Furthermore, for non-stochastic effects, there is a clear causal relationship between radiation exposure and the effect. Examples of non-stochastic effects include sterility, erythema (skin reddening), ulceration, and cataract formation. Each of these effects differs from the other in both its threshold dose and in the time over which this dose must be received to cause the effect (i.e., acute vs. chronic exposure).

5.4 Factors Influencing the Occurrence of Health Effects

The type and probability of occurrence of health effects resulting from exposure to ionizing radiation is a function of several interrelated factors.

5.4.1 Dose and Dose Rate

The effect of ionizing radiation upon humans or other organisms is directly dependent upon the size of the dose received. The dose, in turn, is dependent upon a number of factors including the strength of the source, the distance from the source to the affected tissue, and the time over which the tissue is irradiated.

The ability of a given dose of ionizing radiation to cause health effects is influenced by the rate at which the dose is imparted. Because of various repair process which occur within the human body, a given dose of radiation in excess of that needed to produce a particular non-stochastic effect may, in fact, not produce such an effect if the dose is imparted over a relatively long period of time (i.e. chronic exposure). It is conservatively assumed, however, that dose rate is not a critical factor in controlling the probable occurrence of stochastic effects such as cancer or genetic damage.

5.4.2 Chronic vs. Acute Exposures

Long-term exposures to relatively low levels of ionizing radiation are referred to as chronic exposures. As indicated by the previous section, such exposures have little potential for inducing non-stochastic health effects and are of concern because of their potential for initiating cancer or genetic damage. Short-term exposures to relatively high levels of ionizing radiation are referred to as acute exposures. Such exposures have the potential for producing both non-stochastic effects (e.g. erythema, epilation, and ulceration) as well stochastic effects (e.g. cancer) in the irradiated tissue.

5.4.3 Whole Body vs. Localized Exposure

The effectiveness of a given dose of external radiation in causing biological damage is dependent upon the portion of the body irradiated. For example, because of differences in the radiosensitivity of constituent tissues, the hand is far less likely to suffer biological damage from a given dose of radiation than are the gonads. Similarly, a given dose to the whole body has a greater potential for causing adverse health effects than does the same dose to only a portion of the body.

Section Assessment #5

1) *Describe how free radicals are formed and how they damage the body.*
2) *Define the term radio-sensitivity and give two examples of highly radio-sensitive cells.*
3) *What is the difference between a stochastic effect and non-stochastic effect?*
4) *What are the three factors that influence the occurrence of health effects after an exposure to radiation?*

6.0 EXPOSURE LIMITS

Concern over the biological effects of ionizing radiation began shortly after the discovery of X-rays in 1895. From that time to the present, numerous recommendations regarding occupational exposure limits have been proposed and modified by various radiation protection groups, the most important being the International Commission on Radiological Protection (ICRP). These guidelines have, in turn, been incorporated into regulatory requirements for controlling the use of materials and devices emitting ionizing radiation.

Table 2 Summary of Dose Limits [10 CFR 835.202]

Type Of Exposure	**Limit**
General Employee: Whole Body (internal + external) (TED)	5 rem/year
General Employee: Lens of Eye (external)	15 rem/year
General Employee: Extremity (hands and arms below the elbow;	50 rem/year
General Employee: Any organ or tissue (other than lens of eye)	50 rem/year
Declared Pregnant Worker: Embryo/Fetus (internal and external)	0.5 rem/gestation period
Minors: Whole body (internal + external	0.1 rem/year
Minors: Lens of the eye, skin, and extremities	10% of General Employee

Notes:

1. The weighting factors in Appendix 2B, 10 CFR 835 shall be used in converting organ dose equivalent to effective dose equivalent for the whole body dose.
2. The annual limit of dose to "any organ or tissue" is based on the committed dose equivalent to that organ or tissue resulting from internally deposited radionuclides over a 50-year period after intake plus any deep dose equivalent to that organ from external exposures during the year.
3. Exposures due to background radiation, as a patient undergoing therapeutic and diagnostic medical procedures, and participation as a subject in medical research programs shall not be included in either personnel radiation dose records or assessment of dose against the limits in this Table.
4. See Appendix 2C for guidance on non-uniform exposure of the skin.
5. Whole body dose (TED) = effective dose equivalent from external exposures + committed effective dose equivalent from internal exposures.
6. Lens of the eye dose equivalent = dose equivalent from external exposure determined at a tissue depth of 0.3 cm.
7. Shallow dose equivalent = dose equivalent from external exposure determined at a tissue depth of 0.007 cm.

6.1 Basis of Recent Guidelines

In general, the guidelines established for radiation exposure have had as their principle objectives: (1) the prevention of acute radiation effects (e.g., erythema, sterility), and (2) the limiting of the risks of late, stochastic effects (e.g., cancer, genetic damage) to "acceptable" levels. Numerous revisions of standards and guidelines have been made over the years to reflect both changes in the understanding of the risk associated with various levels of exposure and changes in the perception of what constitutes an "acceptable" level of risk.

Current guidelines for radiation exposure are based upon the conservative assumption that there is no safe level of exposure. In other words, even the smallest exposure has some probability of causing a latent effect such as cancer or genetic damage. This assumption has led to the general philosophy of not only keeping exposures below recommended levels or regulatory limits but of also maintaining all exposures "as low as is reasonably achievable" (ALARA). This is a fundamental tenet of current radiation safety practice.

6.2 Regulatory Limits for (Radiological Workers) Occupational Exposure

Many of the recommendations of the ICRP and other radiation protection groups regarding radiation exposure have been incorporated into regulatory requirements by various countries. For Department of Energy facilities, radiation exposure limits are found in Title 10, Part 835 of the Code of Federal Regulations (l0 CFR 835). Table 2 provides a summary of the dose limits for occupational external exposures, for those designated at radiological workers.

6.3 Recommended Exposure Limits for Pregnant Workers

Because of the increased susceptibility of the human embryo and fetus to damage from ionizing radiation, established dose limits to the embryo/fetus are much lower than for adults. 10 CFR 835.206(a) requires that the dose equivalent to the embryo/fetus from the period of conception to birth, as a result of occupational exposure of a declared pregnant worker be limited to 500 mrem. Workers who find that they are pregnant are encouraged to declare their pregnancy in writing to their supervisors; the Laboratory will then take steps to keep exposures within the stated limit. Forms for declaring pregnancy are available from ESH&A (G40 TASF).

6.4 Prenatal Radiation Exposure

DOE and Ames Laboratory policies encourage female radiological workers to voluntarily notify their supervisors in writing via the Declaration of Pregnancy Form (10202.008) if they become pregnant. Ames Laboratory must provide the option of a mutually agreeable assignment of work tasks, with no loss of pay or promotional opportunity, such that further occupational radiation exposure is unlikely.

For a declared pregnant worker who chooses to continue working as a radiological worker, the following radiation dose limit will apply. The dose limit for the unborn child (during entire gestation period) is 500 mrem. Efforts should be made to avoid exceeding 50 mrem/month to the pregnant worker. If the dose to the unborn child is determined to have already exceeded 500 mrem when a worker notifies her employer of her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

6.5 Regulatory Limits for Non-occupational Exposure

For whole body exposure the non-occupational exposure limit is 100 mrem/yr. This is the limit for persons not designated at radiological workers. This is in addition to the 620 mrem/yr. received, on average, by individuals in the U.S. from natural background radiation and manmade radiation sources. The 100 mrem/yr limit also applies to individuals under age 18 who work in the vicinity of radiation sources.

6.6 Ames Laboratory Administrative Control Levels

The DOE radiation dose limits are established for occupational workers based on guidance from the Environmental Protection Agency (EPA), the National Council on Radiation Protection and Measurements (NCRP), and the International Commission on Radiological Protection (ICRP).

The Facility administrative control levels for radiological workers are in some cases more conservative than the DOE limits and are established to ensure the DOE limits and control level are not exceeded and to help reduce individual and total worker population radiation dose (collective dose). ALARA (Policy 10202.001) establishes an annual administrative control level of 0.5 rems/yr based on historical personnel radiation dosimetry records, current activities, and projected activities involving sources of ionizing radiation at the Ames Laboratory.

For more detail concerning the Laboratory's Personnel Monitoring program see section 10.0 of the Ames Laboratory Radiological Protection Program (RPP) plan.

Section Assessment #6

1) *What is the primary radiation protection organization that sets occupational exposure limits?*
2) *What is the amount of exposure received annually by naturally occurring background radiation?*
3) *Allowable exposure to a declared pregnant worker is (greater, less) than the allowable whole body exposure to a general employee.*
4) *Per the Ames Laboratory Radiological Protection Program (RPP), section 10.0 how frequently does 10 Code of Federal Regulations Part 835 require that occupational dose reports be given to individuals meeting monitoring requirements?*

7.0 RADIATION RISKS IN PERSPECTIVE

Because ionizing radiation can damage the cell's chromosome it is possible that through incomplete repair a cell could become a cancer cell.

7.1 Risk from exposures to ionizing radiation

- We do not know what the risks are at low levels of radiation exposure.
- No increases in cancer have been observed in individuals exposed to ionizing radiation at occupational levels, but the possibility of cancer induction cannot be dismissed because an increase in cancers has not been observed. Risk calculations have been derived from individuals who have been exposed to high levels of radiation.

7.2 Comparisons of Risks

- Acceptance of risk is a highly personal matter and requires informed judgment.
- Most scientists, based on available studies, consider the risks associated with occupational radiation doses acceptable as compared to other occupational risks.
- The following information is intended to put the potential risk of radiation into perspective when compared to other occupations and daily activities.

Table 1 below compares the estimated days of life expectancy lost as a result from exposure to radiation and other health risks. Those estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with normal day-to-day activities that we accept.

Table 1
Average estimated days lost due to daily activities

Health Risk	Average Estimated Days Lost
Unmarried male	3500
Cigarette smoking	2250
Unmarried female	1600
Coal miner	1100
25% overweight	777
Alcohol (U.S. average)	365
Construction worker	227
Driving a motor vehicle	207
100 mrem/year for 70 years	10
Coffee	6

Table 2 below addresses the estimated days of life expectancy lost as a result from exposure to radiation and common industrial accidents at radiation-related facilities and compares these numbers to days lost as a result of fatal work-related accidents in other occupations.

Table 2
Average estimated days lost in other occupations

Industry	Average Estimated Days Lost
Mining/Quarrying	328
Construction	302
Agriculture	277
Radiation dose of 5,000 mrem/yr. for 50yrs.	250
Transportation/Utilities	164
All industry	74
Government	55
Service	47
Manufacturing	43
Trade	30
Radiation accidents (deaths from exposure)	<1

Average estimate days lost was calculated by recording how old workers was when they died from apparent causes, subtracting this from the normal lifespan and averaging over the population sample number.

The Table 3 below shows radiation exposures associated with some common sources and activities such as a chest x-ray, radon gas, etc.

Table 3

Source/Activity	Average Dose per Year
5 hours jet plane ride	3 mrem
Building materials	4 mrem
Chest x-ray	8 mrem
Soil	30 mrem
Internal to our body	35 mrem
Mammogram	40 mrem
Radon gas	138 mrem
CT scan	2500 mrem
Smoking 20 cigarettes per day	5300 mrem to smoker's lungs
Cancer treatment	5,000,000 mrem to the tumor

Section Assessment # 7

1) *Radiation worker radiation exposure limit is 5,000 mrem. Which occupation in Table 2 above has the greatest average days of life lost given their occupation, a miner or a radiation worker?*

2) *Is the average days of life lost greater for smokers in comparison to being 25% over weight? If a person incurred 100mrem/year for 70 years how many estimated days of life would you potentially lose?*

3) *We know what all the risks are at low levels of radiation exposure. True or False.*

8.0 RADIATION CONTAMINATION CONTROL

This section is designed to inform the worker of sources of radioactive contamination. It will also present methods used to control the spread of contamination.

Put simply, radioactive contamination is just radioactive materials somewhere it should not be. Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment. It is important for all employees to recognize potential sources of contamination as well as to use appropriate contamination prevention methods.

8.1 Comparison of Radiation and Radioactive Contamination

Radiation is energy, contamination is material. Exposure to radiation does NOT result in contamination.

Ionizing radiation - the energy (particles or rays) emitted from radioactive (unstable) atoms that can cause ionization. Ionization is the process of removing electrons from atoms.

Radioactive material – any material that contains radioactive (unstable atoms). Unstable atoms emit radiation.

Radioactive contamination –Radioactive material where it is not wanted is referred to as radioactive contamination. Not all radioactive materials is considered “contamination”. Sealed radioactive sources are in a form that isolates the material from spreading. Sealed sources emit radiation and are not a contamination hazard. Contamination may be fixed, removable/transferable, or airborne.

8.2 Types of Radioactive Contamination

Radioactive contamination can be grouped into three types; fixed, removable or airborne.

- **Fixed contamination**: Contamination that cannot be readily removed from surfaces. It cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, etc.) Over time it may "weep," leach or otherwise become loose or transferable.
- **Removable/transferable contamination**: Contamination that can readily be removed from surfaces. It may be transferred by casual contact, wiping, brushing or washing. Air movement across removable/transferable contamination could cause airborne contamination.
- **Airborne contamination**: Contamination suspended in air. This creates a particular hazard because of the possibility of intake by inhalation. Inhalation is the most common mode of uptake of radioactive material in the working environment. In addition to the hazard to the worker, radioactive materials may be carried into ventilation systems, material may be deposited on surfaces over a large area, and there is the potential for releases outside of the facility.

8.3 Sources of Radioactive Contamination

Radioactive material can be spread to unwanted locations, resulting in contamination. The following is a list of potential sources of contamination:

- Leaks or breaks in radioactive systems
- Opening radioactive systems without proper controls
- Airborne contamination depositing on surfaces
- Leaks or tears in radiological containers such as barrels, plastic bags or boxes
- Poor housekeeping in contaminated areas
- Excessive motion or movement in areas of higher contamination
- Sloppy work practices, such as cross-contamination of tools, equipment or workers

The following are indicators of possible contamination:

- Leaks, spills, standing water
- Dusty, hazy air
- Damaged radiological containers
- Spurious or unexplained personnel contaminations at exit points to a radiological

buffer area
- Higher than normal background on personnel contamination survey devices
- Airborne monitor alarms

The following are some causes of radioactive contamination:
- Sloppy work practices, such as cross-contamination of tools, equipment, or workers.
- Not wearing gloves, or removing them prematurely.
- Poor housekeeping in contamination areas.
- Opening radioactive materials/system without proper controls.
- Leaking containers or tears in radiological containers such as barrels, plastic bags, boxes, or protective gear.
- Spills, glass breakage, and animal fluids.
- Airborne contamination depositing on surfaces.
- Not adhering to standard operating procedures (such as not checking gloves after handling radioactive materials or working in a potentially contaminates area.
- Emergencies including: fire, tornados, earthquakes, etc.

Section Assessment #8

1) *Sealed radiological sources are typically a contamination hazard? T/F*
2) *What is radiation contamination?*
3) *What are the three types of radiation contamination?*

9.0 RULES FOR THE SAFE USE OF RADIOACTIVE MATERIALS

In general, both internal and external exposures to ionizing radiation can be maintained ALARA through the adherence by radioactive material users to a number of stand procedures, practices and rules.

1. Smoking, eating or drinking shall not be permitted in radionuclide laboratories.
2. Food, beverages and their containers shall not be permitted in the laboratory.
3. Pipetting by mouth shall not be permitted in radionuclide laboratories.
4 Microwave ovens in radionuclide laboratories shall not be used for heating food or beverages for personal use.
5. Individuals who have not been approved for radionuclide use shall not work with or handle radioactive materials.
6. Radionuclide work areas shall be clearly designated and should, to the extent possible, be isolated from the rest of the laboratory. The work area shall be within a hood if the radioactive material to be used is in a volatile form.
7. All work surfaces shall be covered with absorbent paper that should be changed regularly to prevent the build-up of contamination.
8. Work involving relatively large volumes or activities of liquid radioactive material should be performed in a spill tray lined with absorbent paper.
9. Procedures involving radioactive materials should be well planned and, whenever possible, practiced in advance using non-radioactive materials.
10. Protective clothing appropriate for the work conditions shall be worn when working with radioactive materials. This includes laboratory coats, gloves, and safety glasses. Appropriate footwear must always be worn (sandals cannot be worn when working with radioactive materials).

11. When assigned a dosimeter, it shall be worn when working with radionuclides. Dosimeters are not transferable, they are not shared between personnel.
12. All containers of radioactive materials and items, suspected or known to be contaminated, shall be properly labeled (i.e. with tape or tag bearing the radiation logo and the word "radioactive").
13. All contaminated waste items shall be placed in a container specifically designated for radioactive waste. Sharp items such as needles or razor blades shall be placed in a cardboard box, glass bottle or "sharps" container.
14. A radiation survey shall be performed by the radionuclide worker at the end of each procedure involving radioactive materials (the survey may be conducted using a portable survey instrument, wipes, or both depending on the radionuclide used). All items found to be contaminated shall be placed either in the radioactive waste container or an appropriately designated area. Any surfaces found to be contaminated shall be labeled and decontaminated as soon as possible. **The survey should always include a check of personnel for possible contamination. The ESH&A Office will be notified immediately if extensive contamination is found within the laboratory or if any personnel are found to be contaminated.**
15. Record of the types and quantities of radionuclide possessed by each activity supervisor at a given time shall be maintained.
16. Radioactive materials shall be protected from unauthorized removal or access at all times.

Section Assessment #9

1) *Is it permitted for an unauthorized person to use radioactive material as long as they are directly supervised by an authorized user?*
2) *Radiation surveys shall be conducted at the end of a work week. True/False?*
3) *It is ok to wear another worker's dosimetry because it is only important that while you are working with radioactive materials you have dosimeter on. True/False?*

10.0 PERSONNEL RADIATION MONITORING REQUIREMENTS

As a minimum, whole body dosimeters shall be provided to and used by all radioactive material users. At Ames Laboratory, the Health Physics Group issues dosimeters (see Figure 3) to all Radiation Workers. If the Radiation Worker will be coming into contact with materials capable of excessively exposing their extremities, a ring badge will be issued in addition. See the Ames Laboratory Radiological Protection Program (RPP) Plan for 10 CFR 835 requirements for occupational exposure report distribution frequency to dosimetry participants.

Dosimetry is used to provide an indication of the amount of external radiation exposure the wearer has received and must be worn at all times when handling radioactive material or in areas where dosimetry is required. Badges should be stored in an area free from radiation and heat sources to avoid exposure when not being worn. Badges are exchanged quarterly. Group leaders (or designees) are responsible for issuing and collecting badges and returning them to

ESH&A where they will be shipped to the dosimetry vendor for analysis. Dosimetry will not be issued to individuals until all of the required training has been completed.

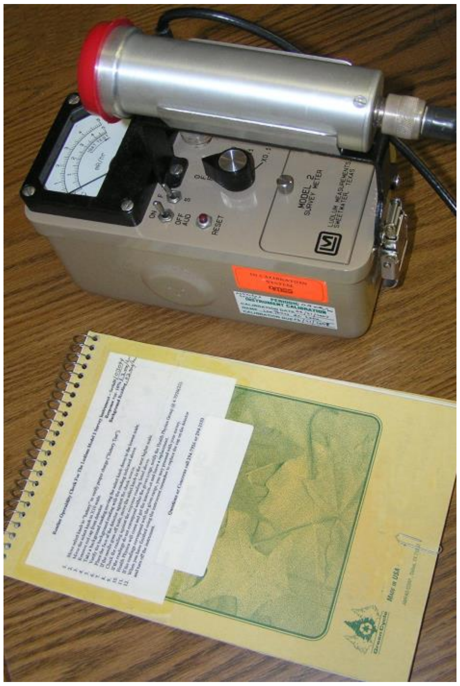
At Ames Laboratory, thermoluminescent dosimeters (TLDs) in the form of whole body badges are issued to radioactive material users. Thermoluminescent dosimeters contain crystalline materials (lithium fluoride) that emit light if they are heated after having been exposed to radiation. The whole body badges typically contain several compartments of crystals with various shields to differentiate the types of radiation to which the badge and wearer are exposed.

Remember that dosimetry badges are to be worn only by the person to whom they are assigned and are not to be shared. They are to be worn only for work related to radiological work at the Laboratory.

Figure 3

Dosimetry ring badge Whole body dosimeter badge

Figure 4



10.1 Radiation Detection Instrument

Each radioactive material use laboratory at Ames Laboratory is assigned a Geiger-Muller (GM) survey instrument with an end window detector, as shown in Figure 4, or a GM with a pancake probe. A member of the Health Physics group (HPG) will assign appropriate radiation detection instrumentation for the isotope being used

Prior to using the GM instrument you must perform an operation check. Pre-operational checks involve:

- checking the calibration sticker. Instruments are calibrated annually. Instruments past their calibration date should not be used and should be reported to the HPG,
- checking the battery,
- inspecting for physical damage,
- background check reading (document your reading in the instrument logbook),
- source check reading (document your reading in the instrument logbook), and
- documenting all pre-operational checks in the instrument logbook prior to using the instrument.

Note that readings taken during the pre-operational check should be within +/-10 % of previous readings already recorded in the instrument logbook. If a GM is reading outside of this range, report it to the HPG. If the GM fails any of the pre-operational checks, it should not be used and your results should be reported to the HPG so a properly operating meter can be supplied to you.

10.2 Radiation Survey Requirements

A radiation survey must be performed by the Radiation Worker at the end of each procedure involving radioactive material. Results of the survey must be recorded and maintained.

Section Assessment #10

1) *When are radiation surveys of radioactive material areas required?*
2) *Define the term dosimetry.*
3) *Describe the primary type of dosimeter used at Ames Laboratory and how it works.*
4) *Name three things done during a pre-operational check of a Geiger-Muller survey instrument.*

11.0 RESPONSIBILITY FOR RADIOACTIVE MATERIAL USE SAFETY

The responsibility for maintaining radiation exposures from radioactive materials ALARA is shared among the Ames Laboratory line management, ESH&A office, radioactive material use group leader (activity supervisor), and the radioactive material user.

11.1 Ames Laboratory Leadership

In accordance with the specific requirements of Ames Laboratory's RPP, an ALARA Committee has been established that oversees the implementation of Laboratory policies and procedures for the safe use of radioactive materials and radiation generating devices. The committee consists of members of Ames Laboratory's staff and faculty appointed by the Director. In addition, the ALARA Committee reviews all requests for use of radioactive materials and radiation generating devices, reviews records of personnel dosimetry, and decides whether or not authorization for use will be granted.

11.2 ESH&A, Health Physics Group

The ESH&A Health Physics Group is responsible for:

- establishing requirements and standards,
- offering consulting services and institutional training,
- approving all purchases, moves, and transfers of radioactive material,
- conducting laboratory inspections,
- verifying that the appropriate safety program requirements have been met, and
- administering the personnel dosimetry program.

11.3 Group Leader/Activity Supervisor

The individual authorized by the ALARA Committee as the activity supervisor on an activity involving the use of radioactive material or a radiation generating device is responsible for all activities conducted under the scope of that authorization. This includes responsibility for ensuring that:

- all individuals working on the activity are appropriately trained and supervised,
- the ALARA Committee has formally authorized all individuals working on the activity,

- all rules, regulations, and procedures for the safe use of radiation generating devices are observed during the activity,
- an accurate record of radioactive material possession is maintained,
- the ESH&A Office is notified of any proposed changes in the storage or use of the radioactive material or radiation generating device prior to the implementation of such changes,
- all uses of radiation are evaluated to further reduce exposures to individuals (ALARA),
- all radioactive sources or source material are protected from unauthorized access or removal (radioactive material must be physically secured or in the direct custody of an authorized user within the lab),
- all standard operating procedures are current and distributed appropriately, and
- a list of qualified radioactive material users authorized for particular experimentation processes in each respective laboratory is maintained.

11.4 Radioactive Material User

Authorized radioactive material users are responsible for:

- keeping their personal exposure as low as reasonably achievable,
- wearing their assigned dosimetry appropriately,
- knowing and following the standard operating procedures for radioactive material experiments,
- notifying their supervisors of any unsafe or hazardous work situations,
- conducting radiation contamination surveys of your radioactive material experiment area during and following experiment cycles,
- completing all required training, and
- assisting the laboratory supervisor in maintaining required records.

Section Assessment #11

1) Who oversees implementation of the Laboratory's RPP?

2) Name three things for which a radioactive material user is responsible.

12.0 RADIOACTIVE MATERIAL

For these topic areas please see the Ames Laboratory's Radiation Protection Program Plan (Plan 10202.004), section 12.

12.1 Procurement
12.2 Security, Storage and Transfer of Radioactive Material
12.3 Decontamination Procedure

(Table 2, Limits of radioactive contamination on surfaces or items)

Section Assessment #12

1) Before placing an order for radioactive material what must you obtain from the ESH&A Office?

2) *All locations where radioactive materials are present must be constantly attended by the trained user or secured to prevent unauthorized removal or tampering. (True or False)*

3) *It is ok to transport your radioactive samples via your personal vehicle as long as it is between Ames Lab buildings and another Department of Energy facility. (True or False)*

4) *Limits of radioactive contamination on surfaces are from what Federal Code?*

13.0 POSTING and LABELING FOR RADIOLOGICAL CONTROL

The goal of a radiological posting and labeling program is to identify and effectively communicate radiological hazards to individuals, allowing them to take the appropriate protective actions. A uniform system of posting and labeling for radiological control is important. The posting and labeling program is implemented to ensure that radiological hazards are adequately controlled in the workplace, and thereby protect the health and safety of workers, the public, and the environment.

10 CFR 835 requires that certain areas and items be posted or labeled to control personnel exposure to radioactive material and ionizing radiation and to prevent the spread of contamination. 10 CFR 835 also provides exceptions to the posting and labeling requirements. These exceptions are allowed only under certain circumstances and, when implemented, apply to posting or labeling only and are not exceptions to entry control requirements

Radiological postings and labels are intended to alert personnel to the locations that are radiological areas or radioactive material areas in order to assist individuals in maintaining exposures as low as reasonably achievable (ALARA). The HPG is responsible for implementation of the posting of controlled spaces. The Laboratory uses 10 CFR 835 and supporting standards as guidance to implement the posting and labeling program.

13.1 Basic Requirements for Postings and Labels

Areas must be posted in accordance with 10 CFR 835 to provide warning to individuals of the presence, or potential presence, of radiation and/or radioactive materials. These areas consist of controlled areas and/or radiological areas. Controlled areas are established to warn individuals that they are entering areas controlled for radiation protection purposes. A radiological area is an area within a controlled area defined as a radiation area, high radiation area, very high radiation area, contamination area, high contamination area, or airborne radioactivity area, in accordance with 10 CFR 835. Additional areas that address specific radiological conditions, such as the radiological buffer area, are recommended in this procedure.

Labeling items and containers for radiation protection/hazard communication purposes is the responsibility of the end user of the radioactive materials. Each item or container of radioactive materials should bear a durable, clearly visible label bearing the standard radiation warning trefoil and the words "Caution, Radioactive Material" or "Danger, Radioactive Material." The label must also provide sufficient information to permit individuals handling, using, or working in the vicinity of the items or containers to take precautions to avoid or control exposures.

Design:

Except as noted, all postings and labels used to designate controlled or radiological areas or radioactive material have the standard radiation warning trefoil in either black or magenta imposed upon a yellow background. Lettering should be magenta or black. Magenta is the preferred color for both the standard radiation warning trefoil and the lettering. The background for the entire sign or label should be yellow.

Signs and labels should be constructed of materials that can endure expected environmental conditions without significant deterioration of color, legibility, strength, or other physical characteristics. Signs and labels should not be altered or defaced in any way to change their meaning. Inserts (on signs containing insert slots) may be changed, as appropriate.

The lettering and standard radiation warning trefoil, if applicable, used for posting should be proportional to the size of the sign or label. Lettering should not be superimposed on the standard radiation warning trefoil (ANSI 1989). The size of lettering used on the sign should not detract from the clarity of the standard radiation warning trefoil. Unless circumstances do not permit, the standard radiation warning trefoil should be oriented with one blade downward and centered on the vertical axis. The standard radiation warning trefoil should be displayed as prominently as is practical.

The color scheme used for radiological posting and labeling should be reserved for radiological hazards communication only. Signs and labels that do not communicate a radiological hazard (e.g., job aids, instructions for removing protective clothing, etc.) should not use the radiological color scheme.

Rope, tape, chains, or similar materials used as boundary identifiers for radiological areas should be yellow and magenta in color. Existing physical barriers used to identify area boundaries do not require color-coding.

All postings for radiation protection purposes at Ames Laboratory are managed by the HPG. The Laboratory uses 10 CFR 835 and supporting standards as guidance to implement the posting and labeling program.

Content:

Signs required by 10 CFR 835 may include radiological protection instructions. Supplemental wording describing additional warnings or directions should be included on the postings or labels. Recommended supplemental wording is discussed in later sections of this procedure.

The actual or anticipated radiological conditions should be included on or with each sign, as applicable, and posted at the entrance points to radiological areas. Other radiological signs containing supplemental wording should be posted clearly and conspicuously to adequately communicate the hazard.

When a sign is used to warn of the potential presence of radiation, an associated statement should be included specifying what conditions will cause the radiation to be present, such as, “POTENTIAL INTERNAL CONTAMINATION” or “CAUTION: EMITS X-RAYS WHEN ENERGIZED”.

Conditions:
Radiological areas are posted based upon actual or potential radiological conditions. Actual conditions are determined through workplace monitoring. Potential conditions are based on professional judgment or experience regarding the likelihood that a radiological condition will exist. When evaluating potential conditions, normal situations as well as unique situations, which can reasonably be expected to occur during the time span of an activity, should be considered.

In many operations, the likelihood that a radiological condition will exist, rather than the actual condition, will define the boundaries and posting of a radiological area. For example, opening a contaminated ventilation system in a non-contaminated area may require a contamination area to be established, or opening a radiological vacuum cleaner in a contamination area may require that an airborne radioactivity area be established. Therefore, it is important that past monitoring data, work-specific experience, and professional judgment be included in the decision on the correct posting of the workplace. These postings should be removed as soon as the conditions requiring them to no longer exist.

Radiological postings should be completed before the commencement of work, updated periodically when changes in radiological conditions occur or are expected, and removed as soon as it is practical when no longer required.

Boundaries and Barriers:
Personnel entry control shall be maintained for each radiological area. 10 CFR 835 lists several methods that may be used to ensure control. The degree of control is to be commensurate with the existing or potential radiological hazard in the area.

One method to ensure personnel entry control is through the use of signs and barricades. Radiological Buffer Areas and radiological areas should be identified by use of a boundary identifier or a physical barrier and sufficient signs. The boundaries of these areas should be appropriately identified (e.g., yellow and magenta floor tape, chains, rope).

Boundary identifiers and physical barriers should be placed so that they are clearly visible from all directions and various elevations to prevent unintentional access to areas, i.e., the barriers cannot be readily walked over or under, except at identified access points. For example, rope barriers should be approximately 24 to 40 inches (60 to 100 cm) in height. Workplace monitoring should be used to determine the adequacy of boundary placement.

Existing physical barriers, such as fences or walls, may be used as boundary identifiers if the posting is adequate to prevent inadvertent access to the radiological area. For example, a wall that can be crossed by ladder could suffice as a boundary identifier but would not prevent an individual from entering an area, thus posting would be required.

Exits from contamination, high contamination, and airborne radioactivity areas (10 CFR 835.2) that are not normally used (e.g., emergency exits or exits secured for contamination control) should be clearly identified. For example, an exit secured for contamination control should be posted with a sign containing the words "EXIT ONLY AT DESIGNATED POINTS."

Controlled Areas:

Controlled areas are established and posted to warn individuals that they are entering areas controlled for radiation protection purposes. All radiological areas lie within the boundaries of controlled areas. Certain areas recommended by this procedure, such as soil contamination areas, do not have to be located inside a controlled area. Individuals who enter only controlled areas without entering radiological areas are not expected to receive a total effective dose equivalent (TED) exceeding 100 millirem in a year.

Each entrance or access point to a controlled area shall be posted whenever radioactive materials or radiation fields which would require posting under 10 CFR 835.603 may be present in the area. The sign should contain wording "CONTROLLED AREA." There are no security requirements at Ames Laboratory that conflict with the choice of sign at the present time.

A controlled area may incorporate one or more radiological areas and/or any radiological buffer areas. Controlled area borders should not be established contiguous with the site boundary. The size of controlled areas should be minimized to ensure positive control and to reduce the number of individuals requiring radiation safety training or escort. Typically, more than one controlled area is established within a site.

Radiological Buffer Area:

Radiological buffer areas are recommended areas, intended to provide secondary boundaries within the controlled area to minimize the spread of contamination and to limit doses to individuals who have not received appropriate radiation safety training. Radiological buffer areas are typically established adjacent to any entrance or exit from a contamination, high contamination, or airborne radioactivity area.

Each entrance or access point to a radiological buffer area should be posted. The sign should contain the standard radiation warning trefoil, a "CAUTION" heading, and the wording "RADIOLOGICAL BUFFER AREA."

Areas of Fixed Contamination:

Areas of fixed contamination are spaces accessible to individuals, that have measured total contamination levels exceeding the total radioactivity values specified in Appendix D of 10 CFR 835 and removable contamination levels less than the removable radioactivity values specified in Appendix D. 10 CFR 835 contains no requirements for posting of these areas; however, it does contain requirements for control of these areas. These requirements are discussed in *Control of Radioactive Contamination* (Procedure 10202.008).

Radioactive Material Area

A radioactive material area is any space accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds ten times the applicable values provided in Appendix E of 10 CFR 835. Each entrance and access point to a radioactive material area is required to be posted.

The standard radiation warning trefoil and the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL must be posted at each radioactive material area as defined in 10 CFR 835.2. Supplemental instructions or warnings to individuals should be included on the sign or posted in conjunction with the sign.

Cabinets, drawers, or containers with greater than 10 times the quantities listed in Appendix E of 10 CFR 835 shall be posted as Radioactive Material Areas if located outside radiological areas and accessible to individuals.

13.2 Exceptions to Posting Requirements

Accessible areas may be excepted from the radiological area posting requirements for transient radiological conditions of less than 8 continuous hours duration when posting is not practical, such as radioactive material transfers, and when individuals who are knowledgeable of and empowered to implement required access and exposure control measures are stationed to provide line of sight surveillance and verbal warnings in lieu of posting. For situations that require only simple access control measures, such as entry prevention, a minimally trained individual such as a security guard would suffice. For situations that require more complicated access and exposure control measures, an individual trained as a radiological control technician should be used. In addition, a sufficient number of these individuals should be used to provide for adequate access and exposure control.

The “Caution, Radioactive Material(s)” posting may be omitted if it is determined that the posting does not convey additional useful information to the worker as under the following circumstances: (1) The area is posted in accordance with 10 CFR 835.603(a) through (f); or (2) Each item or container of radioactive material is labeled in accordance with this subpart such that individuals entering the area are made aware of the hazard; or (3) The radioactive material of concern consists solely of structures or installed components which have been activated (i.e. such as by being exposed to neutron radiation or particles produced in an accelerator).

Packages received from radioactive material transportation, which are labeled and in non-degraded condition should be temporarily isolated in a posted Radioactive Material Area until the monitoring can be conducted. Those found to be in a degraded condition should be monitored prior to receipt from the carrier. For ALARA purposes, the time between package receipt and survey should be minimized.

The exceptions discussed above apply only to radiological area posting requirements and do not apply to the entry control requirements established in 10 CFR 835.501 and 835.502.

13.3 Radioactive Material Labeling

Except as provided in 10 CFR 835.606, each item or container of radioactive material shall bear a durable, clearly visible label bearing the standard radiation warning trefoil and the words “Caution, Radioactive Material” or “Danger, Radioactive Material.” The label shall also provide sufficient information to permit individuals handling or using the containers, or working in the vicinity of the containers, to take precautions to avoid or minimize exposures. The following information should be included on the labels:

1) Contact radiation levels
2) Removable surface contamination levels (specified as alpha or beta-gamma in units of dpm/100 cm2)
3) An estimate of the quantity of radioactivity
4) Mass enrichment
5) Dates surveyed
6) Surveyor's name
7) A description of the source, as appropriate

Items that are too small to be labeled with all of the stated information shall, at a minimum, be labeled with the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL" and the standard radiation warning trefoil. The label shall be placed on a clearly visible location on the item or container. The label should be placed on the exterior of containers holding the radioactive material when the label applied to the radioactive material itself is not visible through the container.

Prior to removal or disposal of empty containers from radiological areas in accordance with 10 CFR 835, the radioactive material label shall be removed or defaced.

Radioactive material includes activated material, sealed radioactive sources, and materials that emit radiation. Radioactive material is also any material, equipment, or system component determined to be contaminated or suspected of being contaminated. Items and equipment located in known or suspected contamination, high contamination, or airborne radioactivity areas shall be treated as radioactive material.

10 CFR 835 provides specific requirements for labeling sealed radioactive sources and these requirements are noted in *Sealed Radioactive Source Accountability and Control* (Procedure 10202.015).

13.4 Contamination Labels

Internally Contaminated Items:
Materials or equipment that is internally contaminated or potentially internally contaminated should be individually labeled. Labels used to identify internally contaminated items should have a "CAUTION" heading and the words "INTERNAL CONTAMINATION" or "POTENTIAL INTERNAL CONTAMINATION", as applicable.

Internally Contaminated Systems:
Installed radiological system components (e.g., pipes, ducts, or tanks) that are, or have the potential to be, internally contaminated are excepted from the labeling requirements of 10 CFR 835.605. However, for ALARA purposes, these systems should be marked or labeled to identify the actual or potential radiological hazard. Labels or markings used to identify internally contaminated systems should have a "CAUTION" heading, and the words "INTERNAL CONTAMINATION" or "POTENTIAL INTERNAL CONTAMINATION," as appropriate. It is acceptable to post the entrances to a single area containing installed radiological systems with a sign stating the radiological status

of the area instead of posting each pipe or duct. The signs should contain the standard radiation warning trefoil, a "CAUTION" heading, and the wording "INTERNAL CONTAMINATION" or "POTENTIAL INTERNAL CONTAMINATION," as appropriate.

It is acceptable to post the entrance of rooms instead of labeling each system item. In such cases, the sign should contain the radiation symbol, a "CAUTION" heading, and wording equivalent to "INTERNALLY CONTAMINATED SYSTEMS LOCATED WITHIN - CONTACT THE HEALTH PHYSICS GROUP PRIOR TO WORKING ON SYSTEMS" or "POTENTIAL INTERNALLY CONTAMINATED SYSTEMS LOCATED WITHIN - CONTACT THE HEALTH PHYSICS GROUP PRIOR TO WORKING ON SYSTEMS."

Protective Clothing and Equipment:
Personal protective clothing and equipment should be specifically identified by a color, symbol, or appropriate labeling that is unique to clothing to be used for radiation protection purposes. Hard hats and other personal protective equipment dedicated for use in contamination, high contamination, or airborne radioactivity areas should be specifically identified by a unique color or marking. The type of identification used for individual types of personal protective clothing and equipment should be uniform. In any case, the type of identification used should be distinct enough so that radiological protective clothing can be easily distinguished from other Ames Laboratory-issued protective clothing and equipment.

13.5 Exceptions to Labeling Requirements

Containers and items are excepted from the radioactive material labeling requirements of 10 CFR 835.605 when:

1) The items or containers are used, handled, or stored in radiological areas posted and controlled in accordance with 10 CFR 835.603 and 835.604 and sufficient information is provided to permit individuals to take appropriate protective actions. This information should be provided on or in conjunction with the area postings or in the controlling work authorization for that area; or
2) The quantity of radioactive material is below the values specified in Appendix E of 10 CFR 835. For containers that contain numerous items of radioactive material, the determination of the need for labeling should be based upon the sum of the activities of the individual items; or
3) Packaged and labeled in accordance with the regulations of the Department of Transportation or corresponding DOE Orders; or
4) Accessible only to individuals authorized to handle or use them, or to work in the vicinity. In such situations, the individuals should be trained as radiological workers and knowledgeable of the types and quantities of radioactive material present in the area; or
5) Installed in manufacturing or process equipment, such as reactor components, piping, and tanks.

Labels applied to sealed radioactive sources may be excepted from the color specifications of 10 CFR 835.601(a) but must provide the individual with sufficient information to identify the item as radioactive. Labels are applied to sealed sources upon receipt.

Section Assessment #13

1) *All postings and labels used to designate controlled or radiological areas or radioactive material must have what design elements?*

2) *For Radiation hazard signs and labels lettering should be magenta or black for both the standard radiation warning trefoil and the lettering. The background for the entire sign or label should be yellow. (True or False)*

3) *Name three things for which a radioactive material user is responsible.*

14.0 RADIOACTIVE WASTE MANAGEMENT

For this topic area please see the Ames Laboratory's Radiation Protection Program Plan (10202.004), section 17.0.

Section Assessment #14

1) *What document should you consult for guidance related to radioactive waste management?*

2) *What Ames Laboratory organization should you contact for questions regarding the collection, processing and disposal of radioactive waste?*

3) *Liquid radioactive waste can be bulked together whether it is an aqueous or organic solvent. (True or False)*

4) *The Laboratory's green tag program requires that property such as lab equipment, including desks, chairs and lab components, is surveyed by your group leader and cleared before release to the warehouse. (True or False)*

15.0 RADIATION SAFETY REFERENCES

Radiation Protection, 3rd edition, Jacob Shapiro, Harvard University Press, Cambridge, Massachusetts, 1990.

Introduction to Health Physics, 3rd edition, Herman Cember, Pergamon Press, New York, NY 1996.

Radiologic Science for Technologists, 2nd edition, Stewart Bushong, The C.V. Mosby Company, St. Louis, Missouri, 1980.

The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, National Academy Press, Washington, D.C., 1980.

Atoms, Radiation, and Radiation Protection, J.E. Turner, Pergamon Press, Oxford, England, 1995.

16.0 DEFINITIONS

Absorbed Dose: The energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad.

Activity: The rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci).

Administrative Control Level: A numerical dose constraint established at a level below the regulatory limit to administratively control and help reduce individual and collective radiation exposure.

Adult: An individual 18 or more years of age.

Airborne Radioactive Material: Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne Radioactivity Area: Any area, accessible to individuals, where the measured concentration of airborne radioactive material, above background, exceeds or is likely to exceed 10 percent of the derived air concentration (DAC) values listed in Appendix A or Appendix C to 10 CFR 835.

As Low As Reasonably Achievable (ALARA): The approach to radiological protection to manage and control exposures (both individual and collective) to the work force and to the general public to levels as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but a process which has the objective of attaining (and maintaining, if achieved) doses as far below the applicable limits of 10 CFR 835 as is reasonably achievable.

Background Radiation: Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout, as it exists in the environment from the testing of nuclear explosive devices. "Background radiation" does not include radiation from radioactive material, source material, or special nuclear material.

Bioassay: The determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Committed equivalent dose (HT,50): The equivalent dose calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed equivalent dose is expressed in units of rems (or Sv).

Contamination Area: Any area, accessible to individuals, where removable contamination levels exceed or are likely to exceed the surface radioactivity values specified in Appendix D of 10 CFR 835, but do not exceed 100 times those levels.

Controlled Area: Any area to which access is managed in order to protect individuals from exposure to radiation and/or radioactive materials.

Continuous Air Monitor (CAM): An instrument that continuously samples and measures the levels of airborne radioactive materials on a "real-time" basis and has alarm capabilities at present levels.

Declared Pregnant Worker: A worker who has voluntarily declared to her employer (Ames Lab), in writing or by completing Form# 10202.008, Declaration of Pregnancy, her pregnancy for the purpose of being subject to the occupational dose limits to the unborn child as specified in 10 CFR 835.206 and Table 2-1, AL SSRCM. This declaration may be revoked, in writing, or by completing Form# 10202.010, Withdrawal of Pregnancy Declaration, at any time by the declared pregnant worker.

DOE Activity: An activity taken for or by DOE or a DOE operation or facility that has the potential to result in the occupational exposure of an individual to radiation or radioactive material. The activity may be, but is not limited to, design, construction, operation, or decommissioning. To the extent appropriate, the activity may involve a single DOE facility or operation or a combination of facilities and operations, possibly including an entire site or multiple DOE sites.

Dose or Radiation Dose: The generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in this section.

Effective dose (E): The summation of the products of the equivalent dose received by specified tissues or organs of the body (H_T) and the appropriate tissue weighting factor (w_T)--that is, $E = \Sigma w_T H_T$. It includes the dose from radiation sources internal and/or external to the body. For purposes of compliance with this part, equivalent dose to the whole body may be used as effective dose for external exposures. The effective dose is expressed in units of rems (or Sv).

Exposure: Being exposed to ionizing radiation or to radioactive material.

External Dose: That portion of the dose equivalent received from radiation sources outside the body (i.e., “external sources”).

Extremity: Hand, elbow, or arm below the elbow; foot, knee, or leg below the knee.

Eye Dose Equivalent: Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm2).

Generally Applicable Environmental Radiation Standards: Standards issued by the EPA under the authority of the Atomic Energy Act of 1954, as amended, that impose limits on radiation exposures, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.

High Contamination Area: Any area, accessible to individuals, where removable contamination levels exceed or are likely to exceed 100 times the surface radioactivity values specified in Appendix D to 10 CFR 835 or those specified in Table 2-2, AL SSRCM.

High Radiation Area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem (0.001 sievert) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Ionization: Ionization is the process of removing electrons from neutral atoms. If enough energy is supplied to remove electrons from the atom the remaining atom has a + charge. The positively charged atom and the negatively charged electron are called an ion pair. Ionization should not be confused with radiation. Ions (or ion pairs) can be the result of radiation exposure and allow the detection of radiation.

Ionizing Radiation: Energy (particles or rays) emitted from radioactive atoms that can cause ionization. The four basic types of ionizing radiation that are of primary concern in the nuclear industry are alpha particles, beta particles, gamma rays and neutron particles.

Individual: Any human being who may be occupationally exposed to ionizing radiation due to their employment at Ames Laboratory or who is visiting the Laboratory.

Individual Monitoring or Dosimetry Devices (individual monitoring equipment): Devices designed to be worn by a single individual for the assessment of dose equivalent such as whole body dosimeters, ring dosimeters, pocket ionization chambers, and personal ("lapel") air sampling devices.

Limits (dose limits): The permissible upper bounds of radiation doses.

Member of the Public: An individual who is not a general employee. However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

Minor: An individual less than 18 years of age.

Monitoring (radiation monitoring, radiation protection monitoring): The measurement of radiation levels, airborne radioactivity concentrations, radioactive contamination levels or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Non-ionizing Radiation: Radiation that doesn't have the amount of energy needed to ionize an atom is called "non-ionizing radiation." Examples of non-ionizing radiation are radar waves, microwaves and visible light.

Occupational Dose: The dose to ionizing radiation received by an individual in a restricted area or in the course of employment in which the individual's assigned duties involve exposure to radiation and/or to radioactive material. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Person: Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, government agency, any state or political subdivision of, or any political entity within a state, any foreign government or nation or other entity, and any legal successor, representative, agent or agency of the foregoing; provided that person does not include the Department or the U.S. Nuclear Regulatory Commission.

Public Dose: The dose received by a member of the public from exposure to radiation and/or to radioactive materials released by Ames Laboratory, or to another source of radiation either within Ames Laboratory's controlled areas or in unrestricted areas. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research programs.

Rad: Unit of absorbed radiation dose in terms of energy deposited in the tissue. The rad is defined as an absorbed dose of 1 joule of deposited energy per kilogram of tissue.

Radiation (ionizing radiation): Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in 10 CFR 835 and the AL SSRCM, does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light.

Radiation Area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Radioactive Material: Any material containing (unstable radioactive) atoms that emit radiation.

Radioactive Contamination: Radioactive contamination is radioactive material in an unwanted place. There are certain places where radioactive material is beneficial. {It is important to note here, that exposure to radiation does not result in contamination of the worker. Radiation is a type of energy and contamination is a material.}

Radioactivity: Radioactivity is this process of unstable (or radioactive) atoms trying to become stable by emitting radiation.

Radioactive Decay: Radioactive decay is the process of radioactive atoms releasing radiation over a period of time to try and become stable (non-radioactive). Also known as disintegration.

Radioactive Half-life: Radioactive half-life is the time it takes for one half of the radioactive atoms present to decay. After seven half-lives the activity will be less than 1% of the original activity.

Radioactive Material Area: Any area(s), accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds ten times the applicable values provided in appendix E to 10 CFR 835.

Radiological Area: Any area(s) within a controlled area defined as a “radioactive material area,” "radiation area," "high radiation area," "very high radiation area," "contamination area," "high contamination area," or "airborne radioactivity area" in accordance with this section.

Radiological Control Technician: A radiological worker whose primary job assignment involves monitoring of workplace radiological conditions, specification of protective measures, and provision of assistance and guidance to other individuals in implementation of radiological controls.

Real-time Air Monitoring: Measurement of the concentrations or quantities of airborne radioactive materials on a continuous basis.

Rem: The special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem = 0.01 sievert).

Respiratory Protective Device: An apparatus, such as a respirator, used to reduce the individual's intake of airborne radioactive materials.

Sealed Radioactive Source: A radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material.

Survey: An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities or radioactive material present.

Total Effective Dose (TED): The sum of the effective does (for external exposures) and the committed effective dose.

Whole Body: For purposes of external exposure -- head, trunk (including male gonads), arms above the elbow, or legs above the knee.